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## Reporting Summary

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### Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a Confirmed

- ☐ ☒ The exact sample size ( $n$ ) for each experimental group/condition, given as a discrete number and unit of measurement
- ☐ ☒ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
- ☐ ☒ The statistical test(s) used AND whether they are one- or two-sided  
*Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
- ☐ ☒ A description of all covariates tested
- ☐ ☒ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
- ☐ ☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
- ☐ ☒ For null hypothesis testing, the test statistic (e.g.  $F$ ,  $t$ ,  $r$ ) with confidence intervals, effect sizes, degrees of freedom and  $P$  value noted  
*Give  $P$  values as exact values whenever suitable.*
- ☒ ☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
- ☒ ☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
- ☐ ☒ Estimates of effect sizes (e.g. Cohen's  $d$ , Pearson's  $r$ ), indicating how they were calculated

*Our web collection on [statistics for biologists](#) contains articles on many of the points above.*

### Software and code

Policy information about [availability of computer code](#)

Data collection

Spikes and behavioral data were collected using the Plexon MAP system v2.7.0., spike sorting using Plexon Offline Sorter v4.0.

Data analysis

Data analysis was performed using MATLAB 2019a, GroupICATv4.0b, libsvm-3.22, and ndt.1.0.4.  
Custom MATLAB code has been made available at <https://doi.org/10.17605/OSF.IO/5MH4Y>

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### Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

The dataset used in this work has been made available at <https://doi.org/10.17605/OSF.IO/5MH4Y>

### Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

- ☒ Life sciences ☐ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

# Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size	The number of rats ( $n = 9$ ) and the number of neurons ( $n = 1122.9 \pm 41$ neurons each day with all rats and problems combined) were not predetermined by any statistical methods but are comparable to those reported in previous publications in our and other labs in the field. For example, in one recent study (Hirokawa et al., Nature, 2019), 485 neurons were recorded from lateral orbitofrontal cortex (OFC) in 3 rats. Relevant publications are cited in the Methods.
Data exclusions	No animals were excluded from analysis. Unfinished recording sessions (i.e., sessions with less than 480 trials) were excluded.
Replication	Recording experiments were conducted on one group of 9 rats. Each rat finished 5 new odor problems. For analyses that required combining all rats and problems, 500 pseudo-ensembles were generated from the same dataset for replications (dimensionality comparison). For cross-problem and cross-subject analyses, problems or rats were randomly drawn and assigned to different groups for cross-validation (500 repeats). All the analyses were consistent across repeats.
Randomization	There was only one experimental group. All rats went through the same training with the initial shaping and five new odor problems.
Blinding	Not relevant because no group allocation was involved in this study.

# Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

## Materials & experimental systems

n/a	Involved in the study
<input checked="" type="checkbox"/>	<input type="checkbox"/> Antibodies
<input checked="" type="checkbox"/>	<input type="checkbox"/> Eukaryotic cell lines
<input checked="" type="checkbox"/>	<input type="checkbox"/> Palaeontology
<input type="checkbox"/>	<input checked="" type="checkbox"/> Animals and other organisms
<input checked="" type="checkbox"/>	<input type="checkbox"/> Human research participants
<input checked="" type="checkbox"/>	<input type="checkbox"/> Clinical data

## Methods

n/a	Involved in the study
<input checked="" type="checkbox"/>	<input type="checkbox"/> ChIP-seq
<input checked="" type="checkbox"/>	<input type="checkbox"/> Flow cytometry
<input checked="" type="checkbox"/>	<input type="checkbox"/> MRI-based neuroimaging

# Animals and other organisms

Policy information about [studies involving animals](#); [ARRIVE guidelines](#) recommended for reporting animal research

Laboratory animals	9 male Long-Evans rats (175 – 200 g, ~3-month-old, in the beginning of the study).
Wild animals	The study did not use any wild animals.
Field-collected samples	The study did not involve field-collected samples.
Ethics oversight	All behavioral testing was carried out at the NIDA-IRP. Animal care and experimental procedures complied with the U.S. National Institutes of Health (NIH) guidelines and were approved by the Animal Care and Use Committee (ACUC) at the NIDA-IRP.

Note that full information on the approval of the study protocol must also be provided in the manuscript.